Advancing Ocean Science Literacy Through Immersive Virtual Reality Project
Summative Evaluation Report
Inverness Research, Inc.
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INTRODUCTION

In 2019, the Advancing Informal STEM Learning program at the National Science Foundation funded the Advancing Ocean Science Literacy through Immersive Virtual Reality project, a pilot/feasibility and collaborative research project between The Hydrous and the Virtual Human Interaction Lab (VHIL) at Stanford University designed to investigate how immersive virtual reality using head mounted displays can enhance ocean literacy and generate empathy towards environmental issues, particularly among high school girls from different socio-economic backgrounds. The Hydrous was responsible for designing and creating *Explore*, the immersive virtual reality experience, while VHIL was responsible for conducting the research.

Inverness Research served as the external evaluator for the project. Our role was to provide progress monitoring through regular phone calls with project leaders, and to assess the nature and quality of user experiences with *Explore* through formative and summative expert reviews. The original plan was to collect formative data through qualitative evaluation on the nature and quality of participants' experiences with prototypes of the immersive virtual reality activities, and to facilitate expert reviews of the final version of *Explore* with educators from the informal STEM education field. Inverness' work shifted slightly due to COVID and the restrictions on collecting in-person data with target users. In year one, we helped develop a logic model for the project and facilitated four expert reviews of prototype storyboards, narration, and drafts of activities. Project leaders at The Hydrous incorporated the feedback from these reviews as they continued to develop the immersive learning modules further (with support from a separate funding source) along with a kit of materials and activities for use with *Explore* in educational settings. In March of 2022, we conducted another round of expert reviews in person with an expanded set of educators on the near-final version of *Explore*.

This report presents a summary of findings from the evaluation data collected for the summative evaluation. Appendix A contains an overview of technical feedback provided to the project immediately following the summative data collection to help in final refinements to *Explore*.

BACKGROUND ON DATA COLLECTION AND REVIEWERS

For the final reviews of *Explore*, we recruited informal STEM educators in the Bay Area who have experience working with target-age youth in both formal and informal STEM learning environments. We attempted to recruit educators from partners included in the original grant proposal (the Exploratorium and IGNITE). Due to the COVID pandemic, only educators from the Exploratorium were able to participate. In addition, we reached out to educators at XRLibraries (https://www.xrmarin.net) whose work focuses on integrating augmented and virtual reality into libraries, schools and after school programs via presentations, trainings for educators and

classes for students. We also recruited one educator with both formal and informal teaching experience and a marine biology background who participated in the earlier formative reviews. Two of the educators also had teenagers who were willing to review *Explore*. In all, we facilitated reviews with thirteen users over a two-day period.

The nine adults who participated in the evaluation included one nonbinary person, five females and three males. All the adults have experience working with youth in informal settings, and one had formal teaching experience as well. Five of the adults had a great deal of experience with virtual reality, while one had a little and three had almost none. The adults ranged in ages from young adults to middle aged. The four teenagers included two males and two females, ranging in age from 13 to 16. Three of the teens had little to no experience with virtual reality, while one had some experience (primarily gaming). Two were knowledgeable about ocean science (the older youth); the other two had not studied any ocean science in school.

The review process involved users going through the full set of three modules, with Inverness researchers observing them and documenting their comments and questions, followed by an in-depth exit interview about their experiences and thoughts about the modules.

SUMMARY OF FINDINGS ON EXPLORE

The project successfully developed a set of high-quality immersive virtual reality interactives on ocean science that contributed to users' understandings of ocean science, the work of marine biologists, and a sense of connection to and empathy for the ocean. Users were able to easily engage with the technology, valued their experiences, and came away with new ideas and understanding about the ocean and climate impacts on the ocean, and those who conduct research work on the ocean. Users also expressed a sense of connection to the ocean environment after their Explore experience.

The findings in this section are organized as follows: Overall Experience, Main Takeaways, Age Level, Potential Usage, and Technology and Navigation.

Overall Experience

All of the *Explore* users were able to engage in the activities, complete all three modules, come away with new ideas, and enjoy the experience. Only one adult user felt woozy and had to stop after the second module. During the experience, users commented that the experience was "exciting," "peaceful," and "beautiful!" The four teenagers who tested *Explore* thought it was "fun," "really cool," and "interesting." The teens particularly liked the manta ray identification activity, and all reported they would do more modules if they were available.

For example, the Track module with the manta rays was one of the favorites of almost all the users and served as a good introduction to the experience. As two users said:

I think out of all the modules, I paid the most attention to the manta rays one.

I liked the manta ray module a lot.

Users like seeing the manta rays, liked holding the camera and taking pictures, and liked learning about how manta rays are identified and named. Comments during use from users included the following:

Manta rays are really neat!

I named one myself! Yeah!

It's making the picture sound!

My hands are weird.

It's surprising how quickly you are so close to the manta rays.

In the Observe module, users pick up and shine a flashlight on coral reef hot spots, collect coral samples from each of five reefs and place those on a pedestal. Users could pick up the coral samples and manipulate them to examine them more closely; this was an easter egg for users to find and they were not directly asked to do this -- two users did this and enjoyed it. Users also liked the bubbles coming from the reef in the introduction to this activity and found that memorable. As one user said:

Oh, I love all the bubbles!

Users who picked up the coral enjoyed that experience. One user said during this module:

I wonder if can play with this coral? Can I grab two of them? Yeah! I can!

In the Measure module on the changes in coral diversity over time, users liked the segment at the beginning where they go back in time. They liked observing the change over time and the boat sinking. They also liked the feeling of depth in the ocean with this module. As one user said:

That's really cool with the fish and the waves up above!

VR Quality

All of the users were impressed by the quality of the virtual reality, and how realistic the experience was of being underwater. Users said:

> *This is so visually impressive!*
>
> *It is really immersive!*
>
> *I love all the vibrant colors!*
>
> *I liked being able to see behind me in the ocean.*
>
> *This is very similar to being in the Monterey Bay Aquarium.*

And one user commented:

> *I am a scuba diver and this captured that feeling really well. The only thing that was missing was the feeling of pressure.*

The users particularly liked starting in the aquarium and transitioning to under water.

Five of the users have a lot of experience both with engaging youth through virtual reality experiences and facilitating youth to create virtual reality experiences. This group of reviewers gave the quality of the virtual reality in *Explore* very high marks in terms of the frame rate, audio quality, and sense of depth.

Main Takeaways

The goals of *Explore* were to provide users with an immersive educational experience that would contribute to users' appreciating the ocean and developing a sense of connection and empathy with the ocean, understanding the work of marine biologists and seeing themselves in that role, and developing ocean literacy. We saw evidence from users of all of these takeaways.

Appreciating the ocean, and developing a sense of connection and empathy with the ocean

Adults and teens who tested *Explore* all commented on the experience having an impact on their sense of appreciation for the ocean, and a sense of connection and relevance to the ocean. As one adult user said:

> *Explore allows users a chance to see a world most people don't get to see.*

Two other adult users also said:

> *Oceans are beautiful and cool.*
>
> *My main takeaway was feeling a connection to a place I haven't been before.*

Teens using *Explore* also came away feeling a sense of connection to the ocean, and along with the knowledge they gained from interacting with the different modules, feeling differently about the impacts of climate change on the ocean. As two of the teens commented:

> *I think you might feel more interested, connected and engaged by having some firsthand experience with the ocean.*
>
> *A lot of people know about some of the problems -- like coral bleaching -- but being able to see it in more depth makes you think about it differently.*

And one adult user said:

> *It makes me think more about impact, about climate change impact. I have much more awareness of the life cycle of a reef.*

<u>Experiencing/understanding the work of marine biologists</u>

Another key takeaway mentioned by adult and teen users alike was experiencing the work of marine biologists firsthand and developing a better understanding of what that work entails. Adult users identified the following main takeaways related to this theme:

- How to observe, notice, count, and capture data; the different ways scientists observe things
- Different ways of observing
- That research takes time

As two adult users commented:

> *This is a cool introduction to tools scientists might use.*
>
> *It gives you an idea as to what it is a marine scientist does and the tools they use.*

One of the adults also thought that teens might come away feeling like the could have a job as a marine biologist. She said, "If I was a kid, I'd be excited about that!"

Fostering ocean literacy/learning new things

In addition to learning about the work of marine biologists, the adults and teens who tested *Explore* identified key things they learned from participating in this virtual reality experience that they didn't know before about manta rays and about coral reefs. In particular, when asked to identify what they had learned from their experience with the three modules, users said the following:

- More awareness of the life cycle of a reef
- What a manta ray is, that manta rays are identified by their spots, and have names
- What coral reefs release and how that contributes to reef bleaching
- That there are different types of coral, and the coral bleaches over time

As one adult user said:

I learned a lot about a big, floppy kite looking animal!

It is important to note that these were the takeaways for users after one experience straight through all three modules. For users, the initial experience is a primarily focused on the immersion in the ocean and the experience of getting comfortable there and becoming comfortable with the technology and the rules of the interface. Because of the immersive experience, there is only so much content that can be taken in. The project leaders designed *Explore* with additional content in each of the modules (about heat maps, specific types of coral and their characteristics, etc.) in addition to the content understanding required to do the activity successfully in each of the modules. While the takeaways from the initial usage clearly match the goals the project leaders had for this, there is also more layered content the project leaders provided in each of the modules that is accessible to users with subsequent usage. Given the time constraints caused by COVID and the end of the grant, we were unable to test multiple usages.

Age Level

Most educators saw this as appropriate for youth in grades 6-10, and particularly for youth in grades 6-8. But it was important to note that all of the adult users enjoyed this experience as well. As one user said, "I can't think of an age where this wouldn't be appropriate." The high school aged teens we interviewed thought it would be best for the younger teens but also liked it for themselves as well, and particularly for people who don't live near the ocean. As one said:

I think this would be great for anyone, especially for people who live in places where the ocean isn't accessible.

Potential Usage

We asked users about the ways in which they could imagine this being utilized beyond an individual user in their home, in informal STEM education settings and formal ones. Our interviewees said they could imagine a range of uses for this in both of these types of education settings. The educators who work regularly with virtual reality in their after-school programming with youth said they would definitely be using *Explore* with their students as part of the programming they offer. One adult who has had both formal and informal marine biology teaching experience imagined using this with high school students along with real data, having the students look at images of coral reefs, and analyzing data on the health of the reefs.

The teens we interviewed thought it would be very helpful to have this experience in school as a compliment to their usual educational experiences. They thought it would not only make learning more fun but would help them remember more. As one teen said:

> *I think it would help me pay attention and remember more, more than if I was just reading a textbook or watching a video.*

Our interviewees also noted the biggest challenge for utilizing this in larger education settings, either formal or informal -- a lack of headsets for a whole class. In this respect, they thought utilizing this with smaller groups of youth in more informal settings might be more doable.

Technology and Navigation

For the most part, users were able to navigate through *Explore* with few difficulties. In Track, the module about manta rays, for example, users were able to understand that they were holding a camera and almost immediately were able to capture a picture of a manta ray. And in Observe, users were able to quickly pick up the flashlight, make the globe spin, and pick up coral from selected reefs. Users were able to use the hand controls to make multiple choice selections when asked to do that. Most users also took full advantage of the immersive environment -- they looked behind and below them to see what was there. A few users tested the boundaries to see what would happen if they manipulated objects in ways that they weren't explicitly directed to do (such as throwing the coral samples or throwing the flashlight); they were pleased with that experience.

There were a few overarching technical/navigational challenges users encountered and reported. We shared these findings with project leaders immediately following the site visit to be addressed in creating the final version.

One area of challenge is a lack of consistency in how users engage in pointing, selecting, picking up, and moving things from one module to another. We weren't sure if the way that users do each of these activities was consistent from module to module (we wondered if it was supposed to be but was buggy). These should be consistent from module to module. Selecting

things in the module generally worked fine for users but picking something up and moving it was trickier. See Appendix A – Formative Feedback on Each Module or more information on this.

In addition, three people who had very little experience with virtual reality wanted a little more time to adjust to the experience before jumping into the activity in the first module. As one user said:

> *I wanted a little more free time for myself just to explore.*

Another challenge that arose for users came at times when they weren't sure what to do next and didn't feel like they knew how to get help or how to move onto the next module if they wanted to. As one user who has a lot of experience with virtual reality said:

> *It's difficult for users in VR when they aren't sure what to do next. There were a few times in this that I wasn't sure what to do next. What do I do if I can't find the last coral reef in Observe? What do I do after I take some pictures of manta rays but I'm not moving on in the program? Am I supposed to take one more picture? It would help to have some of that explained better so people don't feel stuck.*

And finally, some of the modules engaged users in multiple choice activities. In these activities, users could probably use more information for the multiple-choice items, for example, if they got it wrong, they just get the same information repeated and that wasn't adequate in helping them figure out what else they should look for. As one user who has more experience with virtual reality said:

> *It's important that the guesses they are making in the multiple-choice sections don't seem random but feel more intentional.*

COVID IMPACTS ON THE RESEARCH EFFORTS

The research efforts were stymied due to COVID and restrictions on collecting data during the pandemic. The proposed research questions comparing Immerse and *Explore*, and collection of data on the impact on girls comparing different socio-economic backgrounds were unable to be explored at the level the project initially intended. However, the project was able to capitalize on an opportunity late in the project to do large-scale data collection on group immersive virtual reality experiences with college students utilizing *Explore*. Please see the project's final report for more information on this study.

Importantly, both the immersive virtual reality technology and research questions of interest to the use of immersive virtual technology in education were evolving quickly, even in a time when data collection was limited. The project leaders made important shifts in the work to respond to advancements in technology and to engage in new research opportunities and

explore additional questions of interest to the field, as shared in their final report on the project.

CONCLUSION

The project successfully developed a set of high-quality immersive virtual reality interactives on ocean science that seems highly likely based on our initial reviews to contribute to users' understandings of ocean science, the work of marine biologists, and a sense of connection to and empathy for the ocean. Experts engaged in both the formative and summative stages of reviews of *Explore* saw great potential in utilizing *Explore* in both formal and informal education settings and provided their perspective about the appropriate age level for this resource and ways in which they might utilize this in formal and informal STEM education settings.

APPENDIX A – FORMATIVE FEEDBACK ON EACH MODULE

In this appendix we share the feedback on each of the three modules - Track (manta rays), Observe (coral health), Measure (coral health over time) - that was shared with the project leaders immediately after data collection so refinements could be made before the final version of *Explore* was completed.

Track

There were a few areas of difficulty for users with this module. Some users had difficulty matching the picture they took to the options provided to choose from; some users had a hard time finding any photos that matched. In some cases, the pictures don't match because the orientation of the rays in the options is different from the photo they are trying to match to.

In addition, users don't know how many they have to identify at the start of this activity, so some users took a picture and identified it and waited for something else to happen because they did not know they were to take another picture of a ray. This seemed particularly problematic when the opportunity to name the manta ray was one of the first tasks they had.

Observe

Of the three modules, this was the one that most users had the most questions about what they were supposed to do or it didn't resonate as closely with users compared to the other two module. We found there were both conceptual and activity disconnects in this module -- from utilizing a flashlight to find hot spots (where users were finding the dots that identified a reef using a flashlight vs. utilizing the heat maps present on the globe as it spun around), to collecting coral samples where users are unsure if they are collecting a healthy coral or what it might tell them about the reef. All of this makes it harder for users to connect all the dots.

There were also some technical challenges with this one -- if the user doesn't get the floor set properly, the coral on the pedestals blocks the view of the globe.

There were some interesting explorations users made with this one. While only two people picked up the coral, users who did engage with this were delighted. One user wanted to see if they could pick up more than one -- they ended up with one in each hand and then threw them in the air, which delighted them. Another user threw the flashlight into space just to see what would happen. Another user wanted to be able to zoom in on the hot spots on the globe.

One person wanted to remember which reef the corals they had collected came from (which is tricky because of randomization in the activity, each coral might be from multiple reefs).

Measure

It was difficult for almost all users to place the first quadrat -- selecting it and placing it in a specific place was difficult for many users (one of the places where selecting and placing was either buggy or different from the other modules). For many users, the first placement was out in the ocean instead of down on the coral reef where there were no coral species, but there were fish species which the module didn't count because it focuses on coral diversity (but uses the term "species diversity"). This was confusing for users.

Also in this module, users had difficulty in the multiple-choice activities in choosing the correct answers, and in trusting that what the module identified as the right answer was indeed the correct one. As one user said:

I can count way more colors than they are saying is the right answer.

Many users just ended up just guessing, and if they chose an incorrect answer, they were told to look at the colors to help them (which most users did not find helpful. We wondered if there was an alternative to multiple choice that could be utilized here. Three reviewers suggested being able to point and click at the coral in the quadrat and if the user is correct, the coral would then be outlined or go to a faded color.

One user also wondered if identifying the coral by color work for color blind users.

Another thought the two coral modules seemed connected but manta rays did not seem connected to the other two.